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ABSTRACT

A study examined the extent to which computers affect the writing process. In order to test several hypotheses about writing with a computer 15 experienced writers wrote persuasive letters under four conditions--using pen and paper once and a computer the other three times. All of the subjects were experienced with computers having worked daily or almost daily with the machines on which they were tested. In two of the computer conditions, writers used "Andrew," an advanced computing system and related software. The other advanced work station differed only in the size of its screen. The quantitative measures employed were (1) time spent composing the letter, (2) total words produced, and (3) number of words produced per minute. The results indicated that time to compose was longest in the advanced work station and shortest in the pen and paper condition, while the highest number of words produced was in the advanced work station, with the lowest in the pen and paper. There was no significant difference between conditions on the words per minute measure. The letters also received scores for content and mechanics from two readers and from a third reader when scores were more than one quartile different. Analysis showed that the texts produced in the advanced work station were significantly better. Analysis of revision protocols for 8 of the 15 subjects indicated more planning for the pen and paper copies. The study suggests that if computers are to be used effectively in the writing classroom, students must learn not only word processing, but awareness and adaptation of their writing processes. (Tables and five references are included.) (AEW)

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CDC Technical Report No. 34

Computers and the Writing Process: A Comparative Protocol Study

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Computers and the Writing Process:
A Comparative Protocol Study

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[Paper presented at the University of Pittsburgh Conference on Computers and Writing, May 1986.]

Many of us in education are interested in the effects of computers on writing. But when we sit down to talk about these effects we find we're not all talking about the same thing. Some of us are interested in how computers effect the kind and number of interchanges between student and teacher, how computers effect the amount of peer editing in a classroom, or how computers change people's attitudes about writing. Others of us are interested in how computers effect the written product; others in how it changes the processes by which writing is produced. Still others of us are interested in the changes in writing curriculum that computers might facilitate, or how computers as a technology may help redefine writing itself.

I believe that as educators we must be informed about changes computers bring about in the classroom, in the curriculum, and in the cognitive processes of writers in order that we might make informed choices about when and how to utilize computers in the classroom--and what kind of computers to use. However, when I talk today about effects of computers on writing I will be limiting my discussion to effects on text produced and effects on the process which produces them. I'm going to discuss two

studies: the first, an analysis of writing time, length, and quality of texts produced with computer and with pen and paper by the same writers, attempts to answer the question: "do computers effect writing?"; the second, which follows up on the findings in the first, examines the think-aloud protocols of the writers and begins an analysis of *how* using computers effected these writers.

I would like to acknowledge those who helped me in this work. Dick Hayes was a collaborator on the first study, and Monica Smith did much of the "dirty work" of a protocol study--typing, copying, parsing, coding. They both deserve much thanks.

Study 1: Do Computers Effect Writing?

There is an interesting contradiction between common beliefs about this question and the empirical research we have to answer it. On the one hand, we believe--usually based on our own experiences as writers--that computers help us write more text faster, that with computers we can focus on content rather than mechanics or formatting, and that computers make our writing better because they encourage revision. We *like* writing with computers. We believe that the computer's strengths--speed and vast memory capacity--will help writers and the result, for us and for our students, will be more and better writing.

Unfortunately, there is little conclusive empirical evidence to support our assumptions. In fact, one of the best studies we have of this question seems to contradict them: John Gould in his1980 study, found that expert writers using text editors required 50% more time to compose on text editors than on hard copy. But, this extra time did not lead to "better" writing; there was little difference in quality between letters produced on text-editors and those produced on paper. If computers do indeed improve writing, the effects did not show up in Gould's study as longer or better writing.

Of course, since 1980 technological advances have improved the usability, power,

and attractiveness of text-editors and computer displays. Possibly these design advances have made writing on the computer more efficient and Gould's troubling results are simply outdated.

This first study had two purposes: one, it attempted to partially replicate Gould's experiment, using more advanced machines and editors. Second, it tested several hypotheses about writing with the computer. Specifically, that computers help writers produce more text, produce text faster, and that computers help writers write *better*.

[Figure of experiment overview here]

Fifteen experienced writers wrote persuasive letters in four conditions a hard copy and three computer conditions. All of the subjects were experienced users; they worked daily or almost daily on the machines on which they were tested. In two of the computer conditions writers wrote using "Andrew," an advanced computing system and related software being developed at the Information Technology Center as a joint venture of Carnegie Mellon University and IBM (Morris, *et al*, 1986).

The workstation used in these conditions has a large, bit-mapped , high-resolution display, and a mouse. In the large screen workstation condition the window used for writing was 9 1/2 inches wide and 10 1/2 inches long. The other advanced workstation condition differed only in the size of the screen: it was 9 1/2 inches wide and 6 1/2 inches long, the size of a standard PC or terminal display.

The text-editor for both advanced workstation conditions was developed at the ITC and based on EMACS. Writers move through the document by pointing the mouse and clicking in a scroll bar region. Placement of the cursor for editing the text is done by pointing the mouse and clicking the mouse button. For cutting text, writers used either a delete key or a menu option; pasting was also done via a menu. Control-key EMACS commands are also functional on this system.

In the third, or "standard" computer condition, writers used an IBM-PC and the text-editor MINCE, also based on EMACS. The PC had a 9 1/2 inch by 6 1/2 inch screen and a CRT display. Moving the cursor, moving through the document, and editing are done with control-keys. When writing in the computer conditions, writers were not allowed to use pen and paper notes, nor to get a printout of their texts.

The salient differences between the computers are summarized in the table below.

	workstation	PC
Machine		
speed	16 kilo-baud	9600 baud
resolution	bit-mapped black on gray	CRT green on black
screen size	9 1/2 by 10 1/2 50 lines by 90 characters	9 1/2 by 6 1/2 24 lines by 88 characters
Editor (Note: all computer conditions used display editors.)		
text advancement method	scroll bar and mouse	control-keys
cursor movement	mouse/pointer	control-keys
editing--deleting, cut/pst	mouse/menu; delete key	control-keys

Analyses

I looked at three quantitative measures: time to compose the letter, total words produced, and words produced per minute. Because there was no significant difference in any measure between the workstation large and small conditions, these data were collapsed into a single workstation condition and scores were normalized for topic and order effect.

Time to compose was longest in the advanced workstation condition, and shortest in the hard copy condition. These differences were significant by analysis of variance

($p < .02$). At the bottom of the slide are the results from Gould's study; those of you who are interested might want to note them. I'll be returning to them later.

Time

Cond. 1, workstation	17.40 minutes
Cond. 2, PC	15.12 minutes
Cond. 3, pen-and-paper	13.43 minutes

The second measure--number of words produced--also showed a significant difference ($p < .01$), with the highest mean number of words in the advanced workstation condition, and the smallest mean number of words in the hard copy condition.

Total Words

Cond. 1, workstation	352.79 words
Cond. 2, PC	291.62 words
Cond. 3, pen-and-paper	264.05 words

The words-per-minute measure showed no significant difference between conditions.

So in terms of quantity--both time on task and total words--the advanced computer seems to outperform pen and paper although the PC, or standard computer condition does not. But of course quantity is only half the story.

So, I also collected two measures of writing quality: Independent readers (English teachers with at least five years experience teaching writing) rated each subject's letters using a forced quartile split. The letters received scores for *content*--quality of ideas--and for *mechanics*--sentence- and word level-correctness. Agreement between two raters was 80%. When raters' scores were more than one quartile different, a third reader read and rated the letters. Again, because there were no discernable

difference between the two workstation conditions, the data was collapsed into a single workstation condition. With possible scores ranging from 2 (low) to 8 (high), mean scores for each condition were:

Content

Cond. 1, workstation	5.96
Cond. 2, PC	4.0
Cond. 3, pen-and-paper	5.13

Mechanics

Cond. 1, workstation	5.23
Cond. 2, PC	4.26
Cond. 3, pen-and-paper	5.67

The content measure differences are significant by analysis of variance ($p < .02$). Neuman Keuls analysis shows that the texts produced in the PC condition were significantly poorer ($< .05$) than those produced in the advanced workstation condition. The differences between the PC condition and the hard copy condition were just short of significant. Although the differences in mechanics scores are not significant, the mean scores for the PC condition are again the lowest.

In addition, there was a significant difference ($p < .02$) in *total quality* scores between the workstation and the PC, and between pen and paper and the PC.

Total

Cond. 1, workstation	11.20
Cond. 2, PC	8.26
Cond. 3, pen-and-paper	10.89

I began the discussion of this study with a question: "do computers effect writing?" The answer--as you might expect--is not a simple one; in analyzing written products, I found that writers on the whole produced significantly *more* text with the advanced workstation than they did with pen and paper, AND they produced significantly *better* texts with pen and paper and the advanced workstation than they did with a standard computer. In terms of machine variables, I can't say much yet about WHY these differences occurred, beyond noting that screen size doesn't seem to account for the difference--although most of the letters were short enough to be displayed completely on the small screen. The improvement in performance of subjects in this study over Gould's probably has to do with the differences between line editors and screen editors. Beyond that, these results may be due to machine speed, resolution, method of moving through the text, method of editing--i.e., mouse vs. control keys--or any number of interactions.

These results are encouraging--advances in computer design seem to be on the right track. However, I must temper the encouraging results with two qualifications: first, these subjects were expert writers and experienced users--they were all significantly older and more experienced with both writing and computers than most of our students are. The process by which people become expert computer-writers is unclear; however, it is an important one to ask before we can extrapolate these results to student writers. In addition, the advanced workstation that seemed to help these writers is expensive and not typical of most computers in education today. These advanced machines are not readily available for most writers; in fact, most

computer writers probably use the kind of machine that received mixed reviews in this study.

Study 2: Did the Computer Effect the Writers' Processes?

One way to further explore this problem would be to isolate and manipulate machine variables to try and account for the product differences in the first study. For now, at least, I've taken a different tack: I collected think-aloud protocols of these same writers as they revised their letters to determine if there were process differences which might account for the product differences in the first study.

[Figure of protocol experiment overview]

Eight of the original 15 subjects took part in this second study. They revised two of their original letters to be longer and somewhat more formal essays on the same general topic. In a computer condition, half the subjects revised using the PC; the other half using the advanced workstation. In addition, all 8 subjects also revised a letter in the pen and paper condition. So what I had were think-aloud protocols and texts from the same subjects in computer and pen and paper conditions. Needless to say, these data are very rich and diverse and I'm not going to attempt an exhaustive description of what's there. However, I have noticed interesting differences in two areas which I think are really intriguing. So what you're going to hear today is food for thought--it's suggestive rather than definitive.

After parsing the protocols into clauses I used a simple five part coding scheme, loosely based on the Flower and Hayes process model of composing. With a trained rater I achieved about 85% reliability using this coding scheme. Today I'll be discussing two aspects of the protocols--planning and rereading.

Planning is seen by most writing researchers as a key part of the writing process; it's

also a special interest of mine, both as a researcher and as a teacher. In this study, planning was a broad category and included goal-setting, goal evaluation, and plans for carrying out goals at both a global and a local level. Here are some examples of planning statements:

[Figure of examples of planning]

[Figure of results: planning]

As you can see, there are significant differences ($p < .01$) between the amount of planning done in the computer and hard copy conditions. Note how the numbers for each writer line up, with seven of eight of the writers planning more in the hard copy condition. Flower and Hayes, and Burtis, *et al*, have noted that better writers tend to plan more than poorer writers. Differences in amount of planning may help to explain quality differences in computer and pen-and-paper writing in the first study, although the planning differences were as significant between the advanced workstation and hard copy as between PC and hard copy. These results may have important implications for the teaching of student writers, whose planning for writing even with pen-and-paper, is often minimal.

I have further plans for these data. First, I'm going to see if there is a correlation between planning time and revision quality. And I'd like to look at the kind of planning to see if there are differences in kind between planning in computer and hard copy conditions. In any case, the writers in this study plan less when using a computer than they do when writing with pen and paper.

To get a closer look at the planning processes of these writers, I also looked at **initial planning**, that is, the amount of planning that went on before the writer started to write.

[Figure of initial planning]

You see here that six of eight writers had longer initial planning episodes in the hard copy condition, one had the same length, and one was slightly shorter in the pen and paper condition. These differences were significant ($p < .05$).

In follow-up interviews after the experiment, two subjects gave interesting rival interpretations for this result. One subjects said that when writing with pen and paper, he feels license to just pick up the pencil and then sit and think--plan, if you will; he engages the task by picking up the pencil, but doesn't produce text right away. He said that when writing with a computer there is no comparable act to become engaged with the task without actually beginning to type--"I don't feel like I can just sit and think with my hands on the keyboard--I feel like I have to start typing." The hypothesis here is that when using the computer writers cut short their planning time and begin writing before they're ready.

A different interpretation was offered by another writer who said that when writing with the computer "you can jump right in" because it's easy to delete or change something if you don't like it. Presumably the hypothesis here is that because paper is such an expensive medium--so difficult and time consuming to change--writers spend more time planning when doing pen-and-paper writing; they do the work--the planning--up front to save themselves recopying later. Similarly, on the computer, writers can begin writing sooner, forgoing detailed initial planning because text can easily be changed later. So--there are two intriguing explanations for the planning differences which I think it would be fun to explore.

There were also significant differences ($p < .05$) in the amount of rereading that writers did in the different conditions.

[Figure of rereading]

These results are consistent with what I have heard lots of computer writers say about writing with the computer. Over the last two years, I've talked extensively with computer writers and found that again and again, when talking about problems in writing with the computer, people mentioned reading problems with the computer. They often used words like "It's hard to get a sense of the text" or "I have a hard time reading my writing objectively on the screen." These kinds of comments were amazingly consistent. What these rereading differences might reveal is writers trying to "get a sense of their texts" by rereading more in the computer condition. These results are also consistent with results of three reading experiments I've conducted with Dick Hayes which showed that readers were less efficient in several reading tasks with computers (Haas and Hayes, 1986).

In conclusion, let me put forth an hypothesis: these writers have "learned" to write well with the computer. In the interviews I mentioned earlier, the most experienced computer writers, and those who relied on the computer the most for writing, often mentioned a system for writing with the computer that they had developed themselves--one writer spoke of it as "weaning" herself away from hard copy. Another said that it took a lot of work to develop her "system" for writing with the computer but that she was determined to make it work.

Actually, the question I put forth in the beginning of this paper--do computers effect writers and writing?--is a straw man for it supposes that writers are passive, machines active. Of course, it's really the writers who are the active ones--controlling and effecting themselves. What we see in these protocol data are the evidence of writers--smart, self-aware, resourceful writers--adapting their processes to the medium they're using. How computer writers develop such systems for writing with computers is an interesting research question.

A complimentary hypothesis is that student writers will have difficulty adapting their writing process. We know from research on metacognition that students have a much less well developed sense of their own processes and would be less likely to 1) notice that their writing process was being constrained--or aided--by the machine; and 2) have less self-control over how to adapt their processes. What this suggests is that if computers are to be used effectively in the writing classroom, students must not only receive instruction in word processing skills themselves, but must also be made aware of their own writing processes and how to adapt and modify those processes to the computer. Even if we knew how to teach students this metacognitive control--a big if--we would still have to justify the added instruction time by verifying our intuitive feelings about the benefits of computers for writers. We need more research aimed at determining just how and when using a computer helps writers.

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Study 1: Writing Experiment

Subjects: 15 faculty, administrators, and systems designers

Tasks: Composing persuasive letters

Conditions:

workstation large screen

workstation small screen

pc

pen and paper

Design: Within subjects

Measures:

quantity

* time

*length

*words per minute

quality

*content

*mechanics

*total

Results of Writing Experiment: Quantity

Mean for 15 subjects

Time to Compose

Workstation	17.40 minutes
PC	15.12 minutes
Pen and paper	13.43 minutes

(Gould's results: 30.6 minutes for computer, 19.7 minutes for paper)

Total Words Produced

Workstation	352.79 words
PC	291.62 words
Pen and paper	264.04 words

(Gould's results: 250.7 for computer, 242.4 for paper)

Words-per-Minute

Workstation	20.17
PC	21.00
Pen and paper	20.94

(Gould's results: 8.5 for computer, 13.0 for paper)

Results of Writing Experiment: Quality

Mean for 15 Subjects

(Method: 2 raters; forced quartile split for each subject's four letters; third rater for disagreements of more than one quartile)

Content (low = 2, high = 8)

Workstation	6.0
PC	4.0
Pen and paper	5.1

Mechanics (low = 2, high = 8)

Workstation	5.2
PC	4.2
Pen and paper	5.7

Total (low = 4, high = 16)

Workstation	11.2
PC	8.2
Pen and paper	10.9

Protocol Study

Subjects: 8 experienced writers/users

Task: revising own letter to a "somewhat longer and more formal essay"

Conditions: pen-and-paper and either pc or advanced workstation

Analyses: protocols coded for

- *planning
- *writing
- *evaluating text
- *assessing medium
- *rereading

85% reliability with trained rater

Examples of Planning

I've got to come up with a general first sentence.

Fix that [spelling error] later.

What can I tell him about--the school, the city, the surrounding area?

So my audience is students.

This is probably supposed to be a candid letter, right?

Proportion of protocol statements coded as

Planning

Pen-and-Paper	Workstation	PC
43	34	
46	34	
36	19	
38	29	
37		23
35		11
14		17
52		27

Initial Planning:

Planning statements before text production

Pen-and-paper	Workstation	PC
24	7	
7	1	
59	17	
31	21	
12		8
10		11
58		46
7		7

Proportion of protocol statements coded as

Rereading

Pen-and-paper	Workstation	PC
20	28	
20	36	
25	53	
16	31	
29		49
13		11
57		47
10		27